Evaluation Background

- 152 residences in MA and RI
- Conducted participant surveys
- Collected home attribute data
- Metered DHP systems for ~16 months during 2015 and 2016
Primary Research Objectives

• Determine power and energy savings

• Compare performance of cold climate and non-cold climate systems

• Evaluate system sizing and performance
Locations of Sampled Residences
System Monitoring
System Monitoring
Measuring Airflow: Alnor Balometer
Correlating Airflow and Current
Measuring Airflow: Alnor Balometer Accuracy

Source: LBNL-5983E Figure 14, Adapted (Stratton et al. 2012)
Measuring Airflow: Powered Flow Hood
Sample Data Streams
Equivalent Full Load Hours (EFLH) vs. Season

- **Winter 2015**
  - $n = 98$
  - Median = 154
  - Mean = 442

- **Summer 2015**
  - $n = 114$
  - Median = 171
  - Mean = 218

- **Winter 2016**
  - $n = 60$
  - Median = 305
  - Mean = 451
Equivalent Full Load Hours (EFLH) vs. Season

![Graph showing equivalent full load hours (EFLH) for different seasons and purchase intent categories.](image)
## Energy Savings by Season and Baseline System

<table>
<thead>
<tr>
<th>Season</th>
<th>Baseline System</th>
<th>Sample Size</th>
<th>Electric Usage of DMSHP [kWh]</th>
<th>Baseline Energy Reduction</th>
<th>Net Energy Savings</th>
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# Power Savings by Season and Baseline System

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<tr>
<th>Season</th>
<th>Baseline System</th>
<th>Sample Size</th>
<th>Electric Usage of DMSHP [kW]</th>
<th>Baseline Power Reduction [kW]</th>
<th>Average Peak Period Demand Savings [kW]</th>
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<td>0.25</td>
<td>0.58</td>
<td>0.33</td>
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</tbody>
</table>
Seasonal Efficiency vs. Season

- Winter 2015: $n = 87$, median = 6.0
- Summer 2015: $n = 114$, median = 13.8
- Winter 2016: $n = 57$, median = 8.2
Cold Climate Performance

Winter 2016

- Cold Climate: $n = 34$, $r^2 = 0.96$, $\mu_{HSPF} = 10.81$
- Non Cold Climate: $n = 23$, $r^2 = 0.94$, $\mu_{HSPF} = 9.57$

Average CoP vs. Outdoor Air Temperature
Trade-offs with Primary Heating Systems

- Assumed 0.8 primary system efficiency
- Average prices MA fuel and electric prices from 2015 and 2016
- Observed price ranges from past 10 years
- Web App: https://cadmus.shinyapps.io/dmshp/
Ductless Heat Pump Economic Trade-offs

Primary System Type: #2 Oil

Primary System Efficiency: 0.55

Duct/Hydrmic System Efficiency: 0.85

#2 Oil Rate [$/gal]: 2.1

Electric Rate [$/kWh]: 13.39

DHP Efficiency Curve: Cold-Climate Units

Weather Station: Boston, MA (Logan)

Zoning Factor: 0.25

Breakpoint Temperature

#2 Oil [$/gal]

Electricity [ct/kWh]

Hours at Temperature

Selected Prices
System Sizing

DHP System Capacity vs. Thermal Load of Spaces Served
Average Daily Load to Heat Provided, Example 1

Average DHP Heat Output and Thermal Load
Average Daily Load to Heat Provided, Example 2

Average DHP Heat Output and Thermal Load
Average Daily Load to Heat Provided, Example 3

Average DHP Heat Output and Thermal Load
Average Daily Load to Heat Provided, N=93

Average DHP Heat Output and Thermal Load
Primary Findings

• Determine energy savings
  – Lower EFLH than previously assumed reduce TRM savings

• Compare performance of cold climate and non-cold climate systems
  – Higher performance of cold climate units correlate with HSPF ratings

• Evaluate system sizing
  – Systems sized for heating at low temperatures
Program Recommendations

• Incentivize higher efficiency systems

• Target homes heating with electric resistance or propane

• Displace central air conditioners in new construction
Dave Korn
Vice President, Energy Services
Dave.Korn@cadmusgroup.com

Ari Jackson
Senior Analyst, Energy Services
Ari.Jackson@cadmusgroup.com

Facebook.com/CadmusGroup
@CadmusGroup
Linkedin.com/company/the-cadmus-group